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TITLE

AUTOMATIC REARVIEW MIRROR SYSTEM
USING A PHOTOSENSOR ARRAY

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BACKGROUND OF THE INVENTION

Field of the Invention

10   This invention relates to an automatic rearview mirror
     system for automotive vehicles which automatically
     changes reflectance level in response to glare causing
     light, and more particularly relates to an improved
     automatic rearview mirror system using only a
15   rearwardly facing sensor.

Description of Related Art

     Automatic rearview mirrors and mirror systems have been
20   devised for varying the reflectance level of a variable
     reflectance rearview mirror by reducing the reflectance
     automatically in response to annoying glare light, as
     seen rearwardly of the rearview mirror or mirrors by a
     driver of the vehicle, and by increasing automatically
25   the reflectance to a normal or maximum reflectance
     level when the annoying glare light subsides. These
     automatic mirrors have been changed over the years in

an effort to improve their performance characteristics and associated level of glare protection.

Early automatic rearview mirrors used a rearwardly
5   facing sensor and control circuit to change mirror reflectance. One example of such a "single-sensor" type mirror is described in U.S. Patent No. 4,266,856. In these prior art single-sensor type mirrors, the rear glare light was incident on a rearwardly facing sensor
10   or photocell, such as a photodiode, photoresistor or phototransistor. These mirrors suffered from various problems, however, including the problem that these mirrors would become increasingly sensitive and even "lock-up" in their minimum reflectance level or state
15   as the driver encountered significantly higher light levels in town or city driving. This required the driver to repeatedly adjust the mirror's sensitivity control to prevent such problems.

20   To overcome the problems of single-sensor type mirrors, a non-rearwardly facing photocell for sensing "ambient" light was added. It was believed that the desired reflectance necessary to relieve the driver from glare depended not only on glare light but also on ambient
25   light. Accordingly, these "two-sensor" type mirrors used two separate photocells, one generally facing rearwardly and one generally facing forwardly (or other non-rearwardly facing direction) of the mirror or vehicle. The signals from these two photocells were
30   then compared in some fashion, and when, for example, the glare light from the rear was comparatively high with respect to the "ambient" light, a control circuit would apply a control signal to reduce mirror reflectance. Some examples are described in German
35   Laid-Open Patent No. 3,041,692; Japanese Laid-Open Patent No. 58-19941; and U.S. Patents Nos. 3,601,614; 3,612,666; 3,680,951; 3,746,430; 4,443,057; 4,580,875;

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4,690,508; and 4,917,477. In many of these prior art automatic rearview mirrors, light generally forward of the mirror or vehicle was incident on the second photocell.

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These arrangements, however, also had problems. In some of these mirrors the forwardly facing or "ambient" light sensor was inaccurate because it did not correctly measure ambient light levels since it did not
10 include light generally rearward of the mirror or vehicle. Some examples include the devices described in U.S. Patent Nos. 4,443,057 and 4,917,477. Other prior art devices overcame these deficiencies by providing a control circuit which correctly measured
15 ambient light as a combination of both the forward and rear light levels. Examples of this significantly different approach are described in U.S. Patent Nos. 4,793,690 and 4,886,960.

20 The prior art two-sensor type systems generally provided improved performance over prior art single-sensor type systems but were also more complex and costly. In part, this was because using separate forwardly and rearwardly facing photocells required
25 that the performance characteristics of the two separate photocells, such as photoresistors, be matched appropriately to ensure consistent performance under various operating conditions. Matching photocells such as photoresistors, however, generally involves complex,
30 expensive and time consuming operations and procedures.

Both the prior art single-sensor and two-sensor type mirrors presented additional problems when they were also used to control the exterior side view mirrors.
35 This is because such prior art systems used a common control or drive signal to change the reflectance level of both the interior rearview mirror and the exterior

left and/or right side view mirrors by substantially
the same amount. In U.S. Patent No. 4,669,826, for
example, a single-sensor type mirror system used two
rearwardly facing photodiodes to control both an
5   interior rearview mirror and the left and/or right side
view mirrors based on the direction of incident light
from the rear. Another example includes the two-sensor
type system described in U.S. Patent No. 4,917,477.

10   In rearview mirror systems, however, each of the
interior rearview and exterior side view mirrors may
reflect different source light levels. More
specifically, the inside rearview mirror, left side
view mirror and right side view mirror each enable the
15   driver to view a different portion or zone of the total
rearward area. Of course, there may be some overlap of
the image information contained in each of the three
zones. The situation is further complicated with
multi-lane traffic because each of the mirrors reflects
20   different light levels caused by the headlights of the
vehicles which are following, passing or being passed.
As a result, in the prior art systems, when the
reflectance level of the interior rearview mirror was
reduced to decrease the glare of headlights reflected
25   therein, the reflectance level of the exterior left and
right side view mirrors was also reduced by
substantially the same amount, even though, for
example, the side view mirrors might not be reflecting
the same level of glare light, if any. Accordingly,
30   rear vision in the exterior left and right side view
mirrors could be improperly reduced.

Other prior art two-sensor type systems used a common
ambient light sensor and several rearwardly facing
35   sensors, one for each of the mirrors. An example is
the alternate system also described in U.S. Patent No.
4,917,477. This approach is not satisfactory, however,

because it reduces system reliability and increases complexity and cost.

Finally, some prior anti-glare mirrors used several
5   sensors to control the segments of a variable reflectance mirror. One example is disclosed in U.S. Patent No. 4,632,509, which discloses a single-sensor type mirror using three rearwardly facing photocells to control three mirror segments depending on the
10 direction of incident light from the rear. See also U.S. Patent No. 4,697,883. These prior mirror systems generally have the same problems as the other single-sensor type mirrors. Some other anti-glare mirrors are generally disclosed in U.S. Patent Nos. 3,986,022;
15 4,614,415; and 4,672,457.

Consequently, there is a need for an automatic rearview mirror system for an automotive vehicle having improved reliability and low cost, which accurately determines
20 or otherwise discriminates light levels that the driver will experience as glare without the need for a separate forwardly facing photocell. In addition, as noted above, there is also a need for an automatic rearview mirror system of high reliability and low
25 cost, which accurately determines light levels that the driver will experience as glare, and which can control independently the reflectance of a plurality of mirrors according to the light levels actually reflected by each of the rearview and exterior side view mirrors
30 without the need for additional and separate rearwardly facing photocells. There is also a need for an automatic rearview mirror system that can independently control the segments of a variable reflectance mirror while accurately determining light levels that the
35 driver will experience as glare in each segment of the mirror without the need for additional and separate forwardly and rearwardly facing photocells.

SUMMARY OF THE INVENTION

It is an object of the present invention to overcome the problems of the prior art.

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It is another object of the present invention to provide an automatic rearview mirror system of improved reliability.

10 It is yet another object of the present invention to provide an automatic rearview mirror system that accurately determines light levels that the driver will experience as glare without the need for a separate forward facing sensor or other non-rearwardly facing
15 photocells.

It is another object of the present invention to provide an automatic rearview mirror system of high reliability that accurately determines light levels
20 that the driver will experience as glare, and which can independently control a plurality of mirrors or mirror segments according to different fields of view without the need for additional and separate rearwardly facing photocells.
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According to one aspect of the present invention, using a photosensor array and an appropriate control circuit allows the elimination of separate forwardly facing or other non-rearwardly facing photocells, thereby
30 allowing for lower costs and increased reliability since it is not necessary to match two separate photocells such as photoresistors.

According to another aspect, the present invention
35 which achieves one or more of these objectives relates to a control system for controlling a plurality of variable reflectance mirrors or mirror segments which

change their reflectance in response to a signal from a
drive circuit. The system comprises a plurality of
variable reflectance mirrors, a photosensor array and a
control circuit receiving signals from the photosensor
5   array for controlling the mirrors. The photosensor
array is mountable to view rearwardly of the mirror or
vehicle. The photosensor array comprises a plurality
of sets of photosensor elements corresponding to the
plurality of variable reflectance mirrors. The
10   photosensor elements in each set produce a plurality of
photosensor element signals in response to light
incident thereon. The control circuit determines
control signals, indicative of a desired reflectance
for each of the plurality of variable reflectance
15   mirrors, in response to receiving photosensor element
signals from the photosensor element set for each view
or zone corresponding to the rearview mirror and
exterior side view mirrors and also (or alternatively)
the mirror segments. The control signals control the
20   drive circuit to cause the plurality of variable
reflectance mirrors or mirror segments to assume the
desired reflectance.

According to another aspect, the present invention
25   which achieves one or more of these objectives relates
to an automatic rearview mirror system for an
automotive vehicle comprising at least one variable
reflectance rearview mirror, and an array of sensing
elements to sense light levels in an area rearward of
30   the at least one variable reflectance rearview mirror.
Each of the sensing elements is adapted to sense light
levels of light incident thereon and to output an
electrical signal indicative of the sensed light
levels. The system further comprises a signal
35   processor, connected to the array of sensing elements,
receiving and using the electrical signals indicative
of the sensed light levels from the sensing elements

to determine a first electrical signal indicative of a
background light level in the area rearward of the at
least one variable reflectance rearview mirror and to
determine a second electrical signal indicative of at
5   least one peak light level in the area rearward of the
at least one variable reflectance rearview mirror. The
signal processor determines at least one control signal
indicative of the desired reflectance level of the at
least one variable reflectance rearview mirror from the
10   first electrical signal indicative of the background
light level and the second electrical signal indicative
of the at least one peak light level. The system
further comprises at least one drive circuit connected
to the signal processor and to the at least one
15   variable reflectance rearview mirror for receiving the
at least one control signal and generating and applying
at least one drive signal to the at least one variable
reflectance rearview mirror to drive the at least one
variable reflectance mirror to the desired reflectance
20   level.

According to another aspect, the present invention
which achieves one or more of these objectives relates
to a control system for controlling a plurality of
25   variable reflectance mirrors, each of which change
their reflectance level in response to a drive signal
from an associated drive circuit, for an automotive
vehicle. The system comprises a plurality of variable
reflectance mirrors, and a photosensor array mountable
30   to face substantially towards a rear area. The
photosensor array comprises a plurality of photosensor
element sets. Each set comprises a plurality of
photosensor elements. Each of the photosensor elements
generates a photosensor element signal indicative of a
35   light level of light incident thereon, and each of the
sets corresponds to one of the plurality of variable
reflectance mirrors. The system further comprises a

control circuit, connected to the photosensor array,
for determining and applying a plurality of control
signals. Each of the control signals is indicative of
a desired reflectance level for each of the plurality
5   of variable reflectance mirrors in response to
receiving the photosensor element signals from each of
the plurality of photosensor element sets. The system
further comprises a plurality of drive circuits
connected to the control circuit and to different ones
10 of the plurality of variable reflectance mirrors
associated therewith. Each of the control signals is
output to the drive circuit associated therewith, to
generate and apply a drive signal to each of the
plurality of variable reflectance mirrors causing each
15 of the mirrors to assume a desired reflectance level.

According to another aspect, the present invention
which achieves one or more of these objectives relates
to a control system for controlling at least one
20 variable reflectance mirror for an automotive vehicle.
The system comprises photosensor array means for
sensing light levels in an area rearward of the at
least one variable reflectance mirror and generating
photosensor array signals, means for determining a
25 background light signal from the photosensor array
signals, means for determining a peak light signal from
the photosensor array signals, and means for
controlling a reflectance level of the at least one
variable reflectance mirror using the background and
30 peak light signals.

According to another aspect, the present invention
which achieves one or more of these objectives relates
to a method of controlling the reflectance of at least
35 one variable reflectance mirror comprising the steps of
sensing light levels in an area rearward of the at
least one variable reflectance mirror with an array of

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sensing elements, determining a background light level
from the sensed light levels, determining a peak light
level from the sensed light levels, and controlling a
reflectance level of the at least one variable

5   reflectance mirror using the determined background and
peak light levels.

By using a plurality of photosensor element sets or
sub-arrays on a photosensor array to control a

10   plurality of mirrors and also (or alternatively) mirror
segments, the mirrors may be controlled independently
to vary their reflectance in accordance with the view
associated with each of the photosensor element sets or
sub-arrays.

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These and other objects, advantages and features of the
present invention will be readily understood and
appreciated with reference to the detailed description
of preferred embodiments discussed below together with

20   the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a drawing of an automatic rearview mirror

25   of the present invention, including an expanded view of
a rearwardly facing photosensor array located in the
upper center area of the mirror surface;

Figure 1B is another drawing of an automatic rearview

30   mirror of the present invention, including an expanded
view of the rearwardly facing photosensor array
alternatively located in a bezel or chin of the mirror;

Figure 2 is a drawing of an automotive vehicle with the

35   automatic rearview mirror system of the present
invention;

Figures 3A and 3B are illustrative diagrams of a rearward area as viewed by the photosensor elements of the photosensor array;

5   Figure 4A is a generalized diagram of a photosensor array PA(N,M) having a sub-array S(X);

Figure 4B is a generalized diagram of the photosensor array PA(N,M) and sub-arrays S(0), S(1), S(2) and S(3);

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Figure 5 is another schematic diagram of the photosensor array commonly located on a light sensing and logic circuit;

15   Figure 6 is a schematic block diagram of the automatic rearview mirror system;

Figure 7 is a flow chart illustrating the method of the present invention for controlling the reflectance of a

20   rearview mirror or mirrors;

Figures 8A and 8B are detailed flow charts for steps S150, S160 and S180 of Fig. 7;

25   Figure 9 is a flow chart of the general logic flow of Figs. 7, 8A and 8B for controlling the reflectance of three mirrors; and

Figure 10 is another schematic block diagram of the

30   automatic rearview mirror system of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

I.   The Automatic Rearview Mirror System

5   Figure 1A illustrates an automatic rearview mirror 1
comprising a variable reflectance mirror element 1a and
a single rearwardly facing photosensor 2. The
photosensor 2 is mounted facing rearwardly of the
rearview mirror 1 so that its field of view encompasses

10   an area comprising a rear window area and at least a
portion of either or both side window areas. Also
shown is a switch 3 to allow a driver to manually
control several possible mirror functions, such as an
on-off control switch, a sensitivity adjustment and a

15   force-to-day or a force-to-night switch (i.e., forced
maximum or minimum reflectance levels, respectively).
An expanded view of the photosensor 2, which is
preferably located in an upper center area of the
variable reflectance mirror element 1a as shown, shows

20   a light sensing and logic circuit 26 comprising a
photosensor array 32 and a logic and control circuit 34
(which is not shown in Fig. 1A but is shown in Figure 6
as discussed below). A photosensitive surface of each
of the photosensor elements 32a (shown in Fig. 5) of

25   the photosensor array 32 senses light levels or image
information in a predetermined field of view
encompassing an area located rearwardly of the rearview
mirror 1. A lens 30 images or otherwise focuses the
light information from the predetermined field of view

30   onto the photosensor array 32.

The rearview mirror 1 further comprises a channel mount
1b or other mounting means used to fixedly attach the
mirror 1 to the windshield or headliner area of the

35   vehicle. The rearview mirror 1 is generally adjustable
with respect to the channel mount 1a to allow a driver
to position the mirror for correct viewing of the

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rearward area or scene so that the driver's sightline
through the rearview mirror 1 is aligned approximately
with the vehicle's centerline.

5   Preferably, the photosensor 2 is fixedly mounted on the
adjustable portion of the rearview mirror 1 as shown in
both Figs. 1A and 1B so that the viewing axis of the
photosensor 2 is generally aligned with the viewing
axis of the mirror 1 which is perpendicular to the
10   glass surface of the mirror 1. This approach is
preferable both because of packaging concerns and
because it provides a guaranteed sightline. It is,
however, within the scope of the present invention to
mount the photosensor array 32 so that it is movable
15   with respect to the variable reflectance mirror element
1a of the rearview mirror 1.

More preferably, as shown in Fig. 1A, the photosensor 2
is located in the upper center area of the variable
20   reflectance mirror element 1a. This may be required,
for example, if it is necessary to reduce the bezel
size of the rearview mirror 1. If the photosensor 2 is
located behind a glass surface of the variable
reflectance mirror element 1a, an appropriately sized
25   hole is provided in the protective and reflective
materials of the variable reflectance mirror element
1a. Additionally, a corresponding area within an
active layer of the variable reflectance mirror element
1a may be removed or otherwise rendered inactive to
30   enable the photosensor 2 to view directly the rearward
scene. Alternatively, for manufacturing reasons, the
photosensor 2 may view the rearward scene through the
active layer of the variable reflectance mirror element
1a, in which case it is preferable to compensate for or
35   otherwise negate the effects of reducing reflectance
and correspondingly the transmittance of the variable
reflectance mirror element 1a so that the photosensor 2

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effectively views the rearward scene directly as will
be described later.

Most preferably, a reflective surface is maintained
5   within the hole to both preserve the cosmetic
appearance of the assembly as viewed by the driver and
to maximize the reflective surface. This can be
achieved by providing a very thin metal reflective
layer (100 Å thickness or lower) of aluminum, stainless
10 steel, chromium, or silver, etc., so as to be
sufficiently transmitting for incident light to enable
proper operation of the photosensor array 32 but also
sufficiently reflective to appear mirror-like in the
area of the hole. Alternatively, a reflective tape,
15 which is both sufficiently transmitting and reflective
to achieve the objectives described herein, may be
adhered at the hole region using suitable means such as
an optical adhesive and the photosensor array 32 may
then be mounted behind the optical adhesive.
20 Additionally, thin film stacks such as a solid state
tri-layer of ¼ wave TiO_2, ¼ wave SiO_2 and ¼ wave TiO_2 or
some other single thin film of a high index material
may be mounted behind or coated upon the area of the
hole. Finally, since the preferred photosensor array
25 32 is responsive to both visible light and near
infrared, it is preferable to select a material which
reflects a significant proportion of visible light
while being essentially transparent to infrared.

30 As shown in Figure 1B, the photosensor 2 may also be
located in the bezel or chin of the rearview mirror 1
to view the rearward area directly without any
compensation. Although not shown, the photosensor 2
may also be located on or near the channel mount 1b so
35 that the axis of the photosensor 2, which is
perpendicular to the plane of the photosensor array 32,
is in fixed alignment with the vehicle's centerline

regardless of the adjusted position of the rearview mirror 1.

For other vehicles, such as trucks, the photosensor 2
5 may also be located with each of the external side view mirrors as will be described later.

The lens 30 is preferably a single molded plastic lens approximately 2 millimeters in diameter and is
10 preferably bonded to or in close contact with the photosensor array 32. The lens 30 may, however, include any appropriate image focusing means such as conventional single component optics, holographic lens type optics, binary optics or a microlens. The lens 30
15 preferably is also designed to focus an image of the rearward scene within a field of view defined by a cone. The cone's centerline is perpendicular to the plane of the photosensor array 32 and the cone preferably has an included angle of approximately 100
20 degrees. Thus, the image is focused onto a circular area of the plane of the photosensor array 32. Of course, the photosensor array 32 could be positioned in other than a rearwardly facing direction so long as appropriate lenses or other optics are used to direct
25 the light or image information from the rearward area onto the photosensitive surface of the photosensor array 32.

The pre-positioning of the photosensor array 32 in the
30 rearview mirror 1 depends on whether the automatic rearview mirror system 20 is being used in a left hand or a right hand drive vehicle. In either case, the photosensor array 32 is preferably pre-positioned within the circular area of the focused image so that
35 for either a left or right hand drive vehicle and with only driver adjustment of the rearview mirror 1, the rearward scene imaged onto the photosensitive surface

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of the photosensor array 32 includes the rear window
area and at least a portion of the left and right side
window areas of the vehicle.

5   If a sufficiently large photosensor array 32 is used,
then the pre-positioning of the photosensor array 32 is
not vehicle specific as described above, and a system
20 using a larger photosensor array 32 may be used for
both left and right hand drive vehicles. The larger
10   photosensor array 32 is positioned symmetrically within
the circular area of the focused image described above.
Using the larger photosensor array 32 involves using a
pattern recognition means to determine the approximate
vehicle centerline so that the appropriate portion of
15   the larger photosensor array 32 may be selected
depending on whether the automatic rearview mirror
system 20 is installed in a left or right hand drive
vehicle.

20   Figure 2 illustrates an automatic rearview mirror
system 20 for an automotive vehicle, comprising the
rearview mirror 1, a left side view mirror 4 and a
right side view mirror 5. As will be discussed below,
either or both of the side view mirrors 4 and 5 may be
25   connected to a control circuit of the rearview mirror
1. The mirrors 1, 4 and 5 may be constructed according
to any of the methods known to those skilled in the art
and are generally constructed according to the styling
preferences and specifications of the automotive
30   vehicle manufacturers. The means for mounting the
rearview mirror 1, such as the channel mount 1b, and
the electrical connectors used to connect the mirrors 4
and 5 to the control circuit of the rearview mirror 1
and the vehicle's electrical system may include any one
35   of the many configurations known to those having
ordinary skill in the art. The variable reflectance
mirror element 1a of the mirrors 1, 4 and 5 may be any

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device having more than one reflectance level
corresponding to a specific control or drive signal.
Preferably, however, the variable reflectance mirror
element 1a is an electrochromic mirror.

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As discussed, the photosensor 2 is mounted facing
rearwardly of the rearview mirror 1 so that its field
of view encompasses an area comprising the rear window
area and at least a portion of both the left side

10   window area and the right side window area. The
horizontal and vertical fields of view of the rearward
area as seen by the photosensor 2, and more
particularly by the photosensor array 32, are
illustratively shown in Figures 3A and 3B.

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As shown in Fig. 3A, the photosensor array 32 senses a
field of view divided into three separate zones: a
center zone a, a left zone b (generally corresponding
to the left side window area) and a right zone c

20   (generally corresponding to the right side window
area). Each zone is sensed by a separate set or
sub-array S(X) of photosensor elements 32a (described
with respect to Figs. 4A and 4B) within the photosensor
array 32. The center zone, zone a, generally receives

25   light from the rear window area of the vehicle. This
rear window area is depicted by a trapezoidally shaped
rear window figure superimposed on a first set or sub-
array S(1) of photosensor elements 32a used to sense
light levels in zone a. Zone b includes light from at

30   least a portion of a left side window area. This is
depicted by a trapezoidally shaped left rear side
window figure and a partially shown left front side
window figure superimposed on a second set or sub-array
S(2) of photosensor elements 32a used to sense light

35   levels in zone b. Similarly, zone c includes light
from at least a portion of a right side window area.
This is depicted by a trapezoidally shaped right rear

side window figure and a partially shown right front
side window figure superimposed on a third set or sub-
array S(3) of photosensor elements 32a used to sense
light levels in zone c. Additionally, all three zones
5   include light reflected from whatever fixed body work
and interior trim, head rests, vehicle occupants or
other objects that are within the zones a, b and c.

Also as illustratively shown in Fig. 3A, the
10   photosensor elements 32a in columns 1 to 4 comprise the
third photosensor element set in zone c, the
photosensor elements 32a in columns 6-11 comprise the
first photosensor element set in zone a and the
photosensor elements 32a in columns 13 to 16 comprise
15   the second photosensor element set in zone b. Null
zones are provided between the zones a and b and
between the zones a and c to allow for driver
adjustment of the rearview mirror 1. These null zones
also ensure that the center zone a does not include
20   light or other image information from the side window
areas of zones b and c.

As will be discussed in more detail below, the logic
and control circuit 34 selects photosensor element
25   signals from the first photosensor element set or sub-
array S(1) (shown in Fig. 4B) corresponding to zone a
to control the reflectance level of the rearview mirror
1. Similarly, the control circuit 34 selects
photosensor element signals from the second photosensor
_or_
30   element set sub-array S(2) (shown in Fig. 4B)
corresponding to zone b to control the reflectance
level of the left side view mirror 4, and further
selects photosensor element signals from the third
photosensor element set or sub-array S(3) (shown in
35   Fig. 4B) corresponding to zone c to control the
reflectance level of the right side view mirror 5.
Additionally, for a variable reflectance mirror element

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1a having segments, such as a center, left and right
segment, appropriately defined zones a, b and c, i.e.,
sub-arrays S(1), S(2) and S(3), corresponding to the
mirror segments may be used by the logic and control
5   circuit 34 to control independently the individual
mirror segments.

Figure 3B illustratively shows the preferred embodiment
for the zones of the photosensor array 32. In this
10   embodiment, the logic and control circuit 34 selects
photosensor element signals from three overlapping sets
or sub-arrays S(1), S(2) and S(3) of photosensor
elements 32a corresponding to the three overlapping
zones a, b and c to control, respectively, the
15   reflectance level of the mirrors 1, 4 and 5. More
specifically, the control circuit 34 selects
photosensor element signals from the photosensor
elements 32a in columns 6 to 11 (zone a) to control the
reflectance level of the rearview mirror 1. The
20   control circuit 34 also selects photosensor element
signals from photosensor elements 32a in columns 10 to
14 (zone b) to control the reflectance level of the
left side view mirror 4, and further selects
photosensor element signals from photosensor elements
25   32a in columns 3 to 7 (zone c) to control the
reflectance level of the right side view mirror 5.

Additionally, in the Fig. 3B embodiment, the lens 30
focuses or images light information from: (1) the rear
30   window area onto zone a; (2) at least a portion of the
rear window and left side window areas onto zone b; and
(3) at least a portion of the rear window and right
side window areas onto zone c. Contrastingly, in the
Fig. 3A embodiment, the lens 30 focuses light from:
35   (1) the rear window area onto zone a; (2) the left side
window area onto zone b; and (3) the right side window
area onto zone c. The overlapping zones in the Fig. 3B

embodiment are advantageous because each set of
overlapping photosensor elements 32a in zones a and b
and each set of overlapping photosensor elements 32a in
zones a and c, as well as the logic and control circuit

5   34, is able to "preview" the light information that
may, for example, first appear in the rear window area
(and correspondingly in the rearview mirror 1), but
which may appear shortly thereafter in the left or
right side view mirrors 4 and 5. By examining at least

10 a portion of the rear window area, the automatic
rearview mirror system 20 is able to more quickly
respond to annoying glare light from approaching
vehicles or other sources. Overlapping zones are also
generally preferred because a glare light source

15 located in a common or overlapping area of the rearview
mirror 1 and one of the side view mirrors 4 or 5 can
influence both mirrors.

II.   The Light Sensing Device

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The light sensing device of the light sensing and logic
circuit 26 is preferably the photosensor array 32 shown
in Fig. 5. The photosensor array 32 has sufficient
resolution to view the real image of a scene but may

25 also use a spatial distribution of light intensities as
an approximation of the imaged scene. An example of
such a photosensor array is the VLSI Vision Limited
(VVL) Single Chip Video Camera Model #ASIS 1011.

30 Since a photosensor array 32 of the type described,
namely a VVL Single Chip Video Camera, is capable of
providing image information having sufficient
resolution for displaying an actual image or for some
other purpose, it will be readily understood that

35 additional features or functions may be incorporated by
adding circuitry to provide video output from the
photosensor array 32 in addition to the primary control

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functions described herein. For example, the video
output may be output to a CRT, flat LC panel display or
other appropriate display device, located within the
vehicle, to provide a display of the imaged scene for
5   viewing by the driver.

The photosensor array 32 may be located in any of the
mirrors 28 or in any other appropriate location,
whether local or remote, such as on the vehicle's rear
10 bumper, thereby extending significantly the effective
field of view normally available to the driver either
directly or through the vehicle's mirrors 28.
Additionally, the photosensor array 32 may even replace
one or more of the side view mirrors 4 and 5 of the
15 automatic rearview mirror system 20, thereby reducing
the aerodynamic drag on the vehicle while providing
sufficient information to the driver comparable to that
available through the side view mirrors 4 and 5.

20 A video signal from the photosensor array 32 may also
be used by the logic and control circuit 34 to
determine the presence of a vehicle or other object
within the field of view of the photosensor array 32 to
provide a visual signal warning such as through a
25 display panel, or even an audible warning, based on
certain parameters, such as distance and speed of the
object. Additionally, if the photosensor array 32 is
located in the rearview mirror 1, the video signal may
be used to monitor the vehicle's interior to detect
30 unauthorized intrusion into the vehicle. This may be
achieved by providing electrical power to the mirror's
logic and control circuit 34 from a vehicle power
supply and by activating a vehicle intrusion monitoring
mode when a signal indicates that the vehicle's door
35 and trunk locks have been activated. The logic and
control circuit 34 may be used to continuously monitor
the image from the vehicle's interior thereby allowing

detection of objects or persons moving within the
vehicle, and if movement is detected, another signal
from the logic and control circuit 34 may then activate
an intrusion alarm.

5

It is, however, within the scope of the present
invention for the light sensing device to comprise any
similarly appropriate image or array sensor. When the
light sensing and logic circuit 26 is formed as a very-

10 large-scale-integrated (VLSI) complementary-metal-
oxide-semiconductor (CMOS) device, as is known to those
skilled in the art, the light sensing device will share
a common semiconductor substrate with the logic and
control circuit 34.

15

Preferably, for the described three mirror system, the
photosensor array 32 comprises a plurality of
photosensor elements 32a arranged in 160 columns and 40
rows (a 160 x 40 array) providing a horizontal field of

20 view of approximately 100 degrees and a vertical field
of view of approximately 30 degrees. As discussed,
Figs. 3A and 3B illustratively show a 16 x 4
photosensor array 32. The photosensor array 32 may,
however, comprise any appropriately sized array having

25 an appropriate field of view. For example, the field
of view may be narrower when controlling the segments
of only one mirror. Each photosensor element 32a is
preferably about 10 microns square.

30 As shown in Figure 4A, the photosensor array 32
generally comprises a plurality of photosensor elements
32a arranged in a photosensor array PA(N,M) having N
rows of M columns. When viewing the photosensitive
surface of the photosensor array PA(N,M) in a vertical

35 plane, the lower row is row 1, the top row is row N,
the left hand column is column 1, and the right hand
column is column M. A specific photosensor element is

identified as E(n,m) and the signal indicative of a
light level incident thereon is L(n,m). Also, the sub-
array S(X), where X = 0, 1, 2, . . ., Z, is a
rectangular array having P(X) rows of Q(X) columns of
5 photosensor elements 32a and is located such that its
lower left hand element is photosensor element
E(T(X)),U(X)).

As shown in Figure 4B, a background sub-array S(X)
10 designated S(0) is used to determine a general
background light level B. Signals from the photosensor
elements 32a of each peak sub-array S(X), designated
S(1), S(2), . . ., S(Z), are used to determine a peak
light level P(z) incident on each peak sub-array S(1),
15 S(2), . . ., S(Z). The general background light level
B for background sub-array S(0) and the peak light
level P(z) for each peak sub-array S(X) are then used
to determine a mirror control signal $V_C(z)$ for
controlling at least one mirror or mirror segments
20 associated with each zone.

Figure 5 generally illustrates a logic layout of the
photosensor array 32. The logic and control circuit 34
generates array control signals to control the
25 photosensor array 32. As is well known in the art, the
photosensor array 32 is typically accessed in scan-line
format, with the array 32 being read as consecutive
rows, and within each row as consecutive columns or
pixels. Each photosensor element 32a is connected to a
30 common word-line 33e. To access the photosensor array
32, a vertical shift register 33a generates word-line
signals for each word-line 33e to enable each row of
photosensor elements 32a. Each column of photosensor
elements 32a is connected to a bit-line 33f which is
35 connected to a charge-to-voltage amplifier 33c. As
each word-line 33e is accessed, a horizontal shift
register 33b uses a line 33g to output the bit-line

signals on consecutive bit-lines 33f to an output line
33h connected to the logic and control circuit 34.
Also shown is a voltage amplifier 33d used to amplify
the resulting analog photosensor element signals. The
5   analog photosensor element signals are then output on
line 33h to the analog-to-digital converter 44 and
converted to digital photosensor element signals.

III.   The Logic and Control Circuit
10

Figure 6 shows the light sensing and logic circuit 26
comprising the photosensor array 32 and the logic and
control circuit 34. The logic and control circuit 34
comprises a logic circuit 46, a clock 47, a random-
15   access-memory (RAM) 50, or other appropriate memory,
and a digital-to-analog converter 52. The logic
circuit 46 is preferably a dedicated configuration of
digital logic elements constructed on the same
semiconductor substrate as the photosensor array 32.
20   Alternatively, the logic circuit 46 may also be a
microprocessor comprising a central processing unit
(CPU) and a read-only-memory (ROM). The logic circuit
46 may also be implemented using gate array technology
or any other appropriate hardwired logic circuit
25   technology.

The logic circuit 46 interfaces with the clock 47,
provides array control signals to the photosensor array
32, manages data flow to and from the RAM 50 and
30   converters 44 and 52, and performs all computations for
determining a digital mirror control signal $V_{DAC}(Z)$ for
causing the variable reflectance mirror element 1a to
assume a desired reflectance level. As discussed, the
analog-to-digital converter 44 converts the analog
35   photosensor element signals to the digital photosensor
element signals processed by the logic circuit 46. It
has been found that an eight-bit analog-to-digital

converter 44 provides adequate data resolution for
controlling the mirrors 1, 4 and 5. Preferably, the
analog-to-digital converter 44 is constructed on the
same semiconductor substrate as the photosensor array
5   32 as shown in Fig. 5.

The digital photosensor element signals output to the
logic and control circuit 34 are generally stored in
the RAM 50 for processing. The values of the digital
10 photosensor element signals for the photosensor array
PA(N,M) are correspondingly stored in an array in the
RAM 50 designated RA(N,M). The logic circuit 46
processes the values of each of the digital photosensor
element signals, which are designated Val RA(n,m), to
15 determine an instantaneous or substantially real-time
background light signal B_t for a time period t and at
least one peak light signal P(z). The logic circuit 46
uses these signals, which may also be temporarily
stored in the RAM 50, to determine a digital control
20 signal $V_{DAC}(z)$ to cause at least one mirror or mirror
segment to assume a desired reflectance level. The
digital mirror control signal $V_{DAC}(z)$ is then output to
the digital-to-analog converter 52, which outputs a
corresponding analog mirror control signal $V_c(z)$ to a
25 mirror drive circuit 24. Alternatively, the digital-
to-analog converter 52 need not be used if the logic
circuit 46 generates a pulse-width-modulated (PWM)
mirror control signal to control the mirror drive
circuit 24.
30
The mirror drive circuit 24 comprises mirror drive
circuits 24a, 24b and 24c. The drive circuit 24 drives
mirrors 28, which comprises a rearview mirror 28a
(mirror A), a left side view mirror 28b (mirror B) and
35 a right side view mirror 28c (mirror C). Mirrors A, B
and C correspond, respectively, to the rearview mirror
1, the left side view mirror 4 and the right side view

mirror 5 shown in Fig. 2. It is, of course, within the
scope of the present invention for the mirror A to be a
mirror other than the rearview mirror 1. It is
similarly within the scope of the present invention for
5   the mirror B to be a mirror other than the left side
view mirror 4, and for the mirror C to be a mirror
other than the right side view mirror 5. It is also
within the scope of the invention for the mirrors A, B
and C to be mirror segments or zones of the variable
10   reflectance mirror element 1a where the peak sub-array
S(X) for each zone corresponds to a segment of the
variable reflectance mirror element 1a. Thus, for
example, S(1) may correspond to a center mirror
segment, S(2) may correspond to a left mirror segment
15   and S(3) may correspond to a right mirror segment. Any
other appropriate mirror segmentation scheme may also
be used.

A sensitivity control circuit 42 is used to input a
20   sensitivity signal S to the logic and control circuit
34. In addition, signals from a force-to-day (maximum
reflectance) switch 36, a reverse-inhibit (maximum
reflectance) switch 38 and a force-to-night (minimum
reflectance) switch 40 may also be input to the logic
25   and control circuit 34. The switch 3 of Figs. 1A and
1B may include the sensitivity control circuit 42, as
well as the force-to-day switch 36 and the force-to-
night switch 40.

30   The switches 36, 38 and 40 each generate a signal
causing the logic circuit 46 to override its normal
operation, as will be described with respect to Figs.
7, 8A and 8B, and to output mirror control signals
$V_c(z)$ to the mirror drive circuit 24 causing the
35   variable reflectance mirror 28 to assume a maximum or
minimum reflectance level in accordance with the
appropriate signals from the switches 36, 38 or 40.

Finally, the logic and control circuit 34 may also be used to control a vehicle lighting switch 45 to automatically turn on and off a vehicle's headlights and sidelights. This feature will be further described

5   later.

IV.   Operation of the Invention

Figure 7 shows an overview of the logic flow chart and
10   method for controlling the reflectance levels of any
one or all of the mirrors or mirror segments 28a, 28b
or 28c. It should be understood that the reflectance
level of each of the mirrors 28a, 28b and 28c in the
automatic rearview mirror system of the present
15   invention may be commonly or independently controlled.
Figures 8A, 8B and 9 provide more detail on the logic
and method of Fig. 7.

In step S101 of Fig. 7, light information seen
20   rearwardly of the rearview mirror 1 is incident on the
lens 30. In step S110, light passing through the lens
30 is refracted such that the light information is
imaged or focused onto the photosensitive surface of
the photosensor array 32. In step S120, the logic
25   circuit 46 generates and outputs the array control
signals to the photosensor array 32. In step S130,
photosensor element signals indicative of the light
levels incident on each of the photosensor elements 32a
are generated. In step S140, these photosensor element
30   signals are temporarily stored in RAM or any other
appropriate memory. In steps S150 and S160, the logic
circuit 46 determines values for the background light
signal and the peak light signal for each zone
corresponding to each of the mirrors 28. In step S180,
35   the logic circuit 46 uses the background and peak light
signals of step S150 to determine the control signals
required to cause each of the mirrors 28 to achieve a

desired reflectance level. Also, the logic and control circuit 34 in step S180 reads and processes the states of the optional sensitivity control circuit 42, force-to-day switch 36, force-to-night switch 40 and reverse-

5   inhibit switch 38. In step S200, the mirror drive circuits 24 use the control signals determined in step S180 to generate drive signals to cause the mirrors 28 to assume the desired reflectance levels in step S210.

10 In one embodiment of the invention, the logic circuit 46 determines the background light signal B_t in steps S150 and S160 by calculating the average value of the photosensor element signals, previously stored in RAM in step S140, for the photosensor elements 32a in a

15 lowest row or rows of the photosensor array 32 corresponding to an area below the rear window. With respect to Figs. 3A and 3B, this means that the background light signal B_t is determined from photosensor element signals generated by the

20 photosensor elements 32a located in row D of the photosensor matrix array 32. The logic circuit 46 may then output B_t to the RAM 50 for later processing. The logic circuit 46 may also determine B_t by calculating an average value of all of the photosensor element

25 signals in the entire photosensor array 32. More generally, the background light signal B_t for the rearward scene may be determined by calculating the average value of X percent of the lowest photosensor element signal values in the RAM array RA(N,M), where X

30 is preferably 75, but typically may be in the range of 5 to 100.

Additionally, the background light signal B_t is preferably change-limited to determine a limited

35 background light signal B_{Lt}. The signal B_t may be change-limited, for example, by limiting changes in the background light signal B_t to 2% per time frame. A

time frame may be, for example, 250 milliseconds or any other time relating to the rate at which the logic circuit 46 samples the photosensor element signals from the photosensor array 32. The logic circuit 46

5 determines the change-limited value B_{Lt} used to determine the digital mirror control signal $V_{DAC}(z)$ as follows: $B_{Lt} = B_{L(t-1)} + C_L \times (B_t - B_{L(t-1)})$, where B_{Lt} = the change-limited background light signal for a current time frame t, B_t = the actual or substantially

10 real-time background light signal for the current time frame t, $B_{L(t-1)}$ = the change-limited background light signal for a previous time frame (t-1) and C_L = the change-limit value. Additionally, the background light signal B_t from step S150 may be processed by the logic

15 circuit 46 to determine whether the change limited background light signal B_{Lt} is less than or greater than $B_{L(t-1)}$. If B_{Lt} is greater than $B_{L(t-1)}$, then the logic circuit 46 may use a higher change-limit value C_{LH} to determine B_{Lt}. If the background light signal B_{Lt} is

20 less than or equal to $B_{L(t-1)}$, then the logic circuit 46 may use a lower change-limit value C_{LL} to determine B_{Lt}. The values C_{LH} and C_{LL} are in the range of 0.01 to 2, but are preferably on the order of about 0.02 or 2%.

25 The logic circuit 46 in step S150 also determines the peak light signal P(z) for each zone or sub-array S(X) of the photosensor matrix array 32. The peak light signal P(z) used to determine the appropriate mirror control signal $V_C(z)$ for the mirror 28 may be

30 determined by counting or summing the number of occurrences where the digital value for a photosensor element signal is greater than a peak threshold value F for each zone or sub-array S(X). For the preferred analog-to-digital converter having eight-bit data

35 resolution, the logic circuit 46 generates digital values indicative of light levels of light incident on each photosensor element 32a in the range of 0 to 255

$(2^8 - 1 = 255)$, with headlights resulting in values in the range of about 200 to 255, so that the peak threshold value F is selected to be in the range of about 200 to 255 but is preferably 245. The resulting

5 count or sum P(z) provides a measure of the peak light level for the following reasons.

One design objective of the lens 30 and the photosensor array 32 combination is to be able to measure

10 background light levels in the approximate range of 0.01 to 0.1 lux when driving on sufficiently dark roads. This is achieved by ensuring that the lens 30, photosensor elements 32a and charge-to-voltage amplifiers 33c are able to measure such light levels

15 and by providing a maximum exposure time. The maximum exposure time determines the operating frequency or sampling rate of the system 20. In the case of the described system, 1.5 MHz has been found to be appropriate.

20

By varying the exposure time relative to a general background light level B and using a substantially constant sampling rate, a wide range of background light levels in the range of 0.01 to 1000 lux can be

25 measured. Thus, when the background light level is low, the exposure time is relatively long such that headlights within the rearward area cause the affected photosensor elements 32a to saturate. Correspondingly, for higher background light levels, the exposure time

30 is reduced. Saturation occurs when the incident light charges the photosensor element 32a to capacity so that any excess charge will leak or transfer to adjacent photosensor elements 32a. This charge leakage effect is commonly referred to as "blooming." It has been

35 found that a count of the number of photosensor elements 32a at or near saturation, i.e., those having digital values greater than the peak threshold value F,

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provides an excellent approximation of the peak light
levels and is further described in Fig. 8A. The above
described method effectively extends the range of
measurable light levels for the photosensor array 32.

5

Alternatively, if an anti-blooming device is
incorporated in the photosensor array 32, such as is
well known to those skilled in the art, then the peak
light signal P(z) may be determined by calculating an
10   average value of Y percent of the highest photosensor
element signal values for each zone, where Y is
preferably 10, but may be in the range of 1 to 25.
When using this approach for determining P(z), it is
also preferable to include logic to adjust the sampling
15   rate or operating frequency of the logic circuit 46 to
an appropriate value depending on B_{Lt}.

The general background light signal B, whether B_t or
B_{Lt}, and the peak light signal P(z) for each zone of the
20   photosensor array 32, as determined in steps S150 and
S160, are then used by the logic circuit 46 to
determine a mirror control signal $V_C(z)$ as a function
of the ratio of B^n (n preferably has a value of one but
may typically range from 0.8 to 1.3) to P(z), i.e.,
25   $V_C(z) = f(B^n/P(z))$. The control signal $V_C(z)$ is then
output to the mirror drive circuits 24 in step S180 to
drive the mirrors 28 or segments thereof to their
desired reflectance level in the steps S200 and S210.

30   V.   The Preferred Embodiment

The general lighting conditions of the rearward scene
can be defined as follows: the background light level
of the viewed rearward scene is B and the peak light
35   level for each zone or sub-array S(X) is P(z). A
contrast ratio C(z) may be defined as the ratio of the
peak light level P(z) for each zone to the general

background light level B; thus, $C(z) = P(z)/B$. Given
the background light level B, the human eye can
tolerate varying peak light levels in the viewed
rearward scene up to a particular contrast ratio

5 tolerance C_T. Contrast ratios greater than C_T initially
cause discomfort and are generally known as glare. As
the eye adjusts its light sensitivity to protect itself
from the discomforting peak or glare light levels,
vision is reduced and the glare may become disabling.

10 Thus, the maximum tolerable peak light level P_T of the
viewed rearward scene is equal to the product of the
contrast ratio tolerance C_T and the background light
level B, i.e., $P_T = C_T \times B$.

15 The desired reflectance $R_d(z)$ of a variable reflectance
mirror for each zone is that reflectance level which
reduces a peak light level $P(z)$ to a value equal to the
maximum tolerable peak light level P_T, i.e.,
$P_T = R_d(z) \times P(z)$ or $R_d(z) = P_T/P(z)$, and substituting

20 the expression for P_T, $R_d(z) = (C_T \times B)/P(z)$. However,
the maximum tolerable contrast ratio C_T varies across
the population due to aging and other factors;
accordingly, a sensitivity factor S may be used to
account for this variation in contrast tolerance

25 sensitivity so that $R_d(z) = (S \times C_T \times B)/P(z)$.
Selecting the desired reflectance $R_d(z)$ for each zone
provides maximum information from the rearward scene
viewed in each mirror or mirror segment while reducing
discomforting or disabling peak light levels to

30 tolerable levels.

The mirror control signal $V_c(Z)$ required to obtain the
desired reflectance $R_d(z)$ depends on the particular
variable reflectance mirror element that is used. For

35 electrochromic mirrors, a voltage-reflectance
relationship can be approximated and generally defined.
In general, an electrochromic mirror has a reflectance

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level R having a maximum value of R_1 with an applied
voltage V_{app} of 0 volts. As the applied voltage V_{app} is
increased, the reflectance level R perceptually remains
on the order of R_1 until V_{app} reaches a value of

5 approximately V_1. As V_{app} is further increased, the
reflectance level R decreases approximately linearly
until a minimum reflectance of approximately R_2 is
reached at a voltage V_2. Thus, the applied voltage V_{app}
can be approximately defined as:

10 $V_{app} = V_1 + (R_1 - R) \times (V_2 - V_1)/(R_1 - R_2)$
Substituting desired reflectance $R_d(z)$ for the
reflectance R results in the mirror control signal, the
voltage of which is determined as follows:
$V_c(z) = V_1 + (R_1 - S \times C_T \times B/P(z)) \times (V_2 - V_1)/(R_1 - R_2)$.

15 To obtain a digital value $V_{DAC}(z)$, $V_C(z)$ is scaled by a
factor that is the ratio of the maximum digital value
to the value V_2; thus, for eight-bit data resolution
$V_{DAC}(z) = 255 V_C(z)/V_2$, and substituting for $V_C(Z)$:
$V_{DAC}(z) = 255(V_1 + (R_1 - S \times C_T \times B/P(z)) \times (V_2 - V_1)/(R_1 - R_2))/V_2$.

20

Figure 8A provides further detail on the steps S150 and
S160 where the logic circuit 46 determines the
background and peak light signals. More particularly,
steps S151, S152, S159 and S160 provide two processing

25 loops for sequentially determining the digital values
indicative of the photosensor element signals,
Val RA(n,m), in the RAM array RA(N,M) for each of the
photosensor elements 32a of the photosensor array
PA(N,M).

30

In step S153, a lens correction factor LC(n,m) is
applied to each digital value indicative of the
photosensor element signal, Val RA(n,m), to correct for
the effects of lens 30, which results in a lens

35 corrected digital value of the photosensor element
signal Val $RA_{LC}(n,m)$. These effects are typically
referred to as cosine effects or Lambert's Law effects.
The lens correction factor LC(n,m) depends on the

radial distance of the photosensor element 32a from a central axis of the lens 30, and is typically in the range of 1 to 15 but will depend on the geometry of the lens and the selected photosensor array. The lens

5   correction factor LC(n,m) applied to each Val RA(n,m) may be calculated according to Lambert's Law each time Val RA(n,m) is processed. More preferably, the logic circuit 46 initially stores an array of values LC(n,m) in the RAM 50 for each photosensor element 32a of the

10   photosensor array PA(n,m) during an initialization routine. Alternatively, the size of the photosensor elements 32a of the photosensor array 32 may be adjusted to correct for the lens effects at each photosensor element 32a.

15

As discussed, it has been found that light levels for headlights generally result in an eight-bit digital value greater than a peak threshold value F having a value of about 245. Correspondingly, during non-

20   daylight operation of the automatic rearview mirror system 20, background light levels generally result in eight-bit digital values indicative of the light levels incident on the photosensor elements 32a that are less than or equal to the peak threshold value F.

25

Accordingly, the lens corrected value Val $RA_{LC}(n,m)$ is compared in step S154 to the peak threshold value F. If Val $RA_{LC}(n,m)$ is less than or equal to F it is used to increment a counter B_{Count}, in the logic circuit 46,

30   by 1 in step S157 (thereby indicating that a value less than or equal to F has been identified) and by increasing a value B_{Sum} by the value of Val $RA_{LC}(n,m)$ in step S158, where B_{Sum} is the sum of all the values of Val $RA_{LC}(n,m)$ which are less than or equal to F. The

35   background light signal B_t is then determined in step S161 as follows: $B_t = B_{Sum}/B_{Count}$. If Val $RA_{LC}(n,m)$ is greater than F in step S154, then the logic circuit

46 uses a counter $P(z)$ indicative of the peak light
levels for each of the zones or sub-arrays $S(X)$ of the
photosensor array $PA(N,M)$ which is incremented by 1 as
previously described. More particularly, Val $RA_{LC}(n,m)$
5 is tested in step S155 to determine whether it
originates from a particular zone or sub-array $S(X)$,
where $X = 1$ to Z. If Val $RA_{LC}(n,m)$ does not fall within
a defined zone or sub-array $S(X)$, then $P(z)$ is not
incremented; otherwise, $P(z)$ is incremented in step
10 S156 for the appropriate zone.

If the photosensor array 32 is arranged to view the
rearward area through the active layer of the variable
reflectance element 1a, then a color correction factor
15 CC is applied in step S162 to B_t and $P(z)$ to compensate
for any reduction in transmittance when the reflectance
level (and transmittance) of the rearview mirror 1 is
reduced. The value of CC is determined from the last
calculated value indicative of the digital mirror
20 control signal $V_{DAC}(z)$ applied to the rearview mirror 1.
In step S163, a change-limited background light signal
B_{Lt} is determined as has been described previously.

Figure 8B provides further detail on step S180 where
25 the logic circuit 46 determines the appropriate digital
mirror control signal $V_{DAC}(z)$ for each zone or sub-array
$S(X)$ and corresponding mirror 28. In steps S181 and
S182, $V_{DAC}(z)$ is calculated for each mirror 28. In step
S183, the logic circuit 46 reads a state IN1 of the
30 reverse-inhibit switch 38 and if the vehicle is in
reverse gear so that IN1 is high, then all digital
mirror control signals $V_{DAC}(z)$ are set to 0 in step S184
forcing the mirror 28 to its maximum reflectance level.
In step S185, a state IN2 of the force-to-day switch 36
35 is read and if IN2 is high, then all digital mirror
control signals $V_{DAC}(z)$ are set to 0 in step 186 forcing
the mirror 28 to its maximum reflectance level.

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Finally, in step S187, a state IN3 of the force-to-night switch 40 is read and if IN3 is high, then all digital mirror control signals $V_{DAC}(z)$ are set to 255 (the maximum digital value for eight-bit data resolution) in step S188 forcing the mirror 28 to its minimum reflectance level.

Figure 9 shows another view of the logic flow whereby the rearview mirror, the left side view mirror and the right side view mirror (or alternatively three mirror segments) are independently driven to their desired reflectance levels by the independent and separate control and drive signals using photosensor element signals from three photosensor element sets (i.e., the sub-arrays S(1), S(2) and S(3) of photosensor elements 32a in the photosensor array PA(n,m)). The specific subroutines shown in Figs. 8A and 8B corresponding to the general steps shown in Fig. 7 are also used with the general steps shown in Fig. 9.

In step S201, light incident on the lens 30 is focused in step S210 onto the photosensor array 32 comprising the first, second and third sets of photosensor elements 32a in zones a, b and c, respectively. Next, in step S211, the light incident on the first photosensor element set in zone a generates a first set of photosensor element signals, which, in step S211', are then stored in RAM and later used by the logic circuit 46 to determine a first peak light signal in step S212.

In step S221, the light incident on the second photosensor element set in zone b generates a second set of photosensor element signals, while in step S231, the light incident on the third photosensor element set in zone c generates a third set of photosensor element signals. The second set of photosensor element

signals, generated in step S221 are also stored in step 221' in RAM and then used by the logic circuit 46 to determine a second peak light signal in step S222. Similarly, the third set of photosensor element

5   signals, generated in step S231, is next stored in step S231' in RAM and then used by the logic circuit 46 to determine a third peak light signal in step S232.

In step S213, photosensor element signals generated

10 from selected photosensor elements on which light is incident in step S210 are used to determine the background light signal.

In step S214, the logic circuit 46 uses the background

15 light signal determined in step S213 and the first peak light signal determined in step S212 to determine a first control signal. Similarly, the logic circuit 46 uses the background light signal of step S213 and the second peak light signal determined in step S222 to

20 determine a second control signal in step S224. In the same manner, the background light signal of step S213 and the third peak light signal of step S232 are used by the logic circuit 46 to determine a third control signal in step S234.

25

The first control signal determined in step S214 is used by the drive circuit 24a to generate a first drive signal in step S215. This first drive signal drives the rearview mirror 28a to a desired reflectance level

30 in step S216. Likewise, the second control signal determined by the logic circuit 46 in step S224 is used by the drive circuit 24b to generate a second drive signal in step S225, which is then used to drive the left side view mirror 28b to a desired reflectance

35 level in step S226. Finally, the third control signal determined by the logic circuit 46 in step S234 is used by the drive circuit 24c to generate a third drive

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signal to drive the right side view mirror 28c to a desired reflectance level in step S236. Of course, the first, second and third control signals may also be used to control the segments of a mirror 28.

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Finally, as previously discussed, one advantage of the present invention is that it is able to use a single photosensor array 32 to determine both a background light level and a peak light level for controlling the
10 reflectance level of a mirror. This is especially advantageous where the sensor must be placed outside the interior of the vehicle to view the rearward scene. This may be required, for example, in certain truck type vehicles where only exterior side view mirrors may
15 be used and automatic operation is desired. Accordingly, the photosensor array 32 may be located with each side view mirror. The other electronics for the automatic rearview mirror system 20, described previously, may be located either with the photosensor
20 array 32 in each side view mirror, inside the vehicle cab or elsewhere in or on the vehicle. A desired reflectance level for each exterior side view mirror may then be accurately determined using both the determined background light level and peak light level
25 using only a single photosensor array 32 for each mirror.

VI.   Integrated Headlight Control System

30 It is generally important for driver safety reasons that the headlights and sidelights of operating vehicles are turned on as night approaches or when background lighting levels fall below approximately 500 lux. More particularly, it is desirable to have the
35 vehicle's headlights and sidelights automatically turn on when background lighting levels fall to a

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sufficiently low level and automatically turn off when background lighting levels rise sufficiently.

While there are other automatic headlight control
5   systems, such systems require that the photocells, which are used to control the headlights, be located and positioned so that they generally face upward either to avoid the effects of oncoming headlights for generally forward facing photocells or to avoid the
10   effects of following headlights for generally rearward facing photocells.

An advantage of the automatic rearview mirror system 20 is that the background light signal B_{Lt} may be used to
15   automatically turn on and off a vehicle's headlights and sidelights by controlling the vehicle lighting switch 45. Importantly, since B_{Lt} is determined regardless of the presence of peak light sources, such as oncoming or following headlights, the directional
20   constraints on how and where the sensor is located or positioned are avoided. Accordingly, using the photosensor array 32 of the present invention to provide additional vehicle lighting control functions results in lower costs and improved reliability over
25   other headlight control systems.

The limited background light signal B_{Lt} has been described for the purpose of controlling the reflectance levels of an automatic rearview mirror
30   system 20. Additionally, the logic circuit 46 may use B_{Lt} to generate a vehicle lighting control signal to control the vehicle lighting switch 45 to turn on and off automatically the vehicle's headlights and sidelights. The ability to use B_{Lt} is important because
35   the vehicle lighting switch 45 should not be responsive to rapid or small fluctuations in background light levels in the region of the desired point at which the

$L40$

vehicle lighting switch is turned on or off, i.e., the switch point. Such fluctuations can be caused by the shadowing effect of overhanging trees or structures or the lighting differences between the eastern and

5   western skylines at dawn and dusk which may be encountered when turning the vehicle.

Additionally, hysteresis is also provided between the switch-on and switch-off conditions of the vehicle

10   lighting switch 45 to further stabilize operation of the switch 45 in such fluctuating light conditions. More specifically, if the required switch point for falling light levels is SP, then the switch point for rising light levels is SP x (1 + H), where H is a

15   hysteresis factor typically in the range of about 0.005 to 0.5, but is preferably 0.2. Thus, if B_{Lt} is less than SP, then the vehicle lighting control signal to the vehicle lighting switch 45 is set high to turn on the vehicle's headlights and sidelights. If B_{Lt} is

20   greater than SP x (1 + H), then the vehicle lighting control signal to the vehicle lighting switch 45 is set low to turn off the vehicle's headlights and sidelights.

25   Additionally, if the photosensor array 32 and logic circuit 46 are both powered directly by the vehicle's electrical system through the ignition switch, then a time delay t_d may be provided such that if the ignition switch is turned off when the headlight control signal

30   is set high, the vehicle lighting control signal will remain high for a time t_d and thereafter fall to a low value to turn off the vehicle's headlights and sidelights. A manual control may also be provided to allow the driver to adjust the time delay t_d.

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Finally, the vehicle lighting control signal and, more specifically, the lighting control switch 45 may also

be used to inhibit automatic control of the automatic
rearview mirror system 20. For example, if the vehicle
lighting control signal indicates that the vehicle
lighting should be turned off, then the logic and
5   control circuit 34 may be used to enable sensitivity
switch 42 or some other switch allowing the driver to
manually adjust the reflectance level of the mirrors
28. Thus, the driver may manually select a lower
reflectance level during daylight conditions to provide
10   protection against peak light sources, such as a bright
setting sun. As background light levels fall or during
non-daylight conditions, the vehicle lighting control
signal would indicate non-daylight conditions and the
logic and control circuit 34 may then be used to
15   disable manual control and return the automatic
rearview mirror system 20 to full automatic control.

VII.   The Automatic Rearview Mirror System

20   Figure 10 also shows the automatic rearview mirror
system 20 of the present invention. The system 20 is
powered by the vehicle's electrical system (not shown)
to which the system 20 is connected. A voltage
regulation and transient protection circuit 22
25   regulates power and protects the system 20 from voltage
transients as is well known in the art. The circuit 22
is connected to the vehicle's electrical system and to
ground, and outputs a voltage of up to about 5 volts to
power the mirror drive circuits 24 and the light
30   sensing and logic circuit 26. The circuit 22 also has
a ground line connected to the light sensing and logic
circuit 26.

The 5 volt line is also connected to the force-to-day
35   switch 36 and the reverse-inhibit switch 38 (connected
in parallel to the light sensing and logic circuit 26)
which are used to force the mirrors 28 to their maximum

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reflectance level. More particularly, when either of these switches is closed, they generate a high level signal V_H such as a 3 volt signal, which is input to the light sensing and logic circuit 26. This high

5 level signal overrides the normal operation of the light sensing and logic circuit 26 causing it to output a control signal to the drive circuits 24 to drive the mirrors 28 to their maximum reflectance level. Conversely, when these switches are open, they each

10 generate a low level signal V_L such as a signal of less than 3 volts, thereby permitting normal operation of the light sensing and logic circuit 26, as has been discussed with respect to Figs. 7, 8A and 8B. The force-to-day switch 36 and the reverse-inhibit switch

15 38 may be alternatively configured to generate a low level signal when closed and a high level signal when open. The force-to-day switch 36 is a manually operated switch and is preferably placed on the rearview mirror 28a and may be switch 3. The reverse-

20 inhibit switch 38 is connected to a reverse inhibit line in the vehicle's electrical system (not shown) so that the reverse-inhibit switch 38 is actuated automatically whenever the vehicle is in reverse gear.

25 The force-to-night switch 40, used to force the mirrors 28 to their minimum reflectance level, generates a high level signal V_H when closed and a low level signal V_L when opened. The signal V_H or V_L is then input to the light sensing and logic circuit 26.

30 The high level signal may, for example, be between 3 to 5 volts and the low level signal may be below 3 volts. The high level signal overrides the normal operation of the light sensing and logic circuit 26, as discussed with respect to Figs. 7, 8A and 8B, causing the circuit

35 26 to output a control signal to the drive circuits 24 to drive the mirrors 28 to their minimum reflectance level. The low level signal, on the other hand,

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permits normal operation of the light sensing and logic
circuit 26. Alternatively, the force-to-night switch
40 may be configured to generate a low level signal
when closed and a high level signal when open. The
5   force-to-night switch 40 is also a manually operable
switch, preferably located on the rearview mirror 28a,
and may also be switch 3.

The light sensing and logic circuit 26 is also
10 connected to the sensitivity control circuit 42. The
circuit 42 enables the operator to manually adjust the
sensitivity of the mirrors 28 using the switch 3 (shown
in Figs. 1A and 1B). The sensitivity control circuit
42 (switch 3) may comprise a potentiometer whose
15 voltage may be varied from zero to five volts.
Alternatively, a single resistor may be used to provide
a single preset sensitivity setting that cannot be
changed by the driver.

20 As previously discussed with respect to Figs. 5 and 6,
the light sensing and logic circuit 26 comprises the
photosensor array 32 (or other light sensing device)
and the logic and control circuit 34. These two
devices may be either separate or commonly located on a
25 single semiconductor substrate. The light sensing and
logic circuit 26 is preferably a single VLSI CMOS
circuit.

Also shown in Fig. 10, the light sensing and logic
30 circuit 26 outputs analog mirror control signals having
voltages varying from zero to approximately 5 volts to
the mirror drive circuits 24 and a vehicle lighting
control signal of 0 to 5 volts to the vehicle lighting
switch 45. Alternatively, as previously discussed the
35 light sensing and logic circuit 26 may output a 5 volt
pulse-width-modulated (PWM) signal to the mirror drive
circuits 24. The mirror drive circuits 24 then

generate and apply drive voltages varying from a low
voltage on the order of 0 volts to a high voltage on
the order of 1 volt to drive the mirrors 28. The
actual driving voltage (or current) may, of course, be
5   significantly lower or higher depending on the variable
reflectance mirror element 1a used.

Each of the mirrors 28 preferably comprises a
reflective electrochromic (EC) cell whose reflectance
10   level may be varied from a maximum of anywhere from
approximately 50 to 90 percent to a minimum of
approximately 4 to 15 percent, and having a maximum
driving voltage on the order of about 1 to 2 volts. As
is well known in the art, electrochromic devices change
15   their reflectance level when a voltage or other
appropriate drive signal is applied to the
electrochromic device. The mirrors 28 alternatively
may comprise any other suitable variable reflectance
mirror.
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As previously discussed, it is also within the scope of
the present invention for the light sensing and logic
circuit 26 to be located remotely from the mirrors 28
of the system 20. However, it is preferred that the
25   light sensing and logic circuit 26 be integral with the
rearview mirror 28a such that: (1) the center line of
the field of view of the photosensor array 32 is
substantially perpendicular to the reflective surface
of the rearview mirror 28a; and (2) the horizontal
30   field of view of the photosensor array 32 is aligned
with the horizontal axis of the rearview mirror 28a.
As a result, the photosensor array 32 receives the
light that will be incident on the rearview mirror 28a
as shown in Fig. 6.
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The individual components represented by the blocks
shown in the schematic block diagrams of Figs. 6 and 10

are well known in the art relating to automatic
rearview mirrors, and their specific construction and
operation is not critical to the invention or the best
mode for carrying out the present invention. Moreover,
5   the logic flow charts discussed in the specification
and shown in Figs. 7, 8A and 8B may be implemented in
digital hardwired logic or programmed into well-known
signal processors, such as microprocessors, by persons
having ordinary skill in the art. Since such digital
10 circuit construction or programming per se is not part
of the invention, no further description thereof is
deemed necessary.

While the present invention has been described in
15 connection with what are the most practical and
preferred embodiments as currently contemplated, it
should be understood that the present invention is not
limited to the disclosed embodiments. Accordingly, the
present invention is intended to cover various
20 modifications and equivalent arrangements, methods and
structures that are within the spirit and scope of the
claims.

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